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A STUDY INTO THE LITERATURE ON STIPPLE-STREAK AND RELATED DISEASES OF POTATO

BY

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INSTITUUT VOOR PHYTOPATHOLOGIE.
LABORATORY FOR MYCOLOGY AND POTATO RESEARCH.

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D. ATANASOFF.

> Is there any thing whereof it may be said, See this is new? it hath been already of old time, which was before us.
>
> ECCLES. 1 : 10.

INTRODUCTION.

Looking through the literature on potato diseases in order to see whether the disease recently described as a new disease under the name „Streak" has been known before, the writer came to the unexpected conclusion that this „new" potato disease is in reality one of the oldest if not the oldest known disease of this plant. It became further evident that some of our present conceptions regarding the relation of leaf roll and mosaic disease to the „curl", „Kräuselkrankheit" and „frisolée" of olden days are quite unfounded, and that as far as the nature of these diseases, also called „degeneration" or „running out" diseases, is concerned, many efforts, much of the useless searching in the darkness, which is still being continued in some countries, and much of ink and money could have been saved if we had only known the older literature on this subject.

The object of this paper is to bring together in concised form the literature on this group of diseases.

The entire literature on the running-out diseases from 1775 until 1900, so far as it has been possible to locate it, is treated here. From 1900 until now only the works dealing with streak

or better stipple-streak [1]), which also belongs to the above group of diseases, are being included in this paper. This was done first because the rest of the literature on „running out" diseases since 1900 is fairly well known and easily accessible, and is so extensive, that it would have materially increased the size of this paper; besides with the exception of the works of only a few authors, it is so valueless that it does not merit any consideration.

The literature on „running out" and „degeneration" of potato from agricultural stand point has been also left out. Only few of the most important works which give at the same time extensive bibliographies are included in the list of literature cited, for the sake of those who may try to go again over the literature on degeneration of potato.

A working over of the literature, here under consideration, would take away much of the „individuality" of the various works and besides it would hardly be possible in this case. For this reason every work is treated here separately and in chronologic order.

In a large number of cases, especially in the English works, the authors while discussing the cause, nature, and remedies against curl, kroesziekte or Kräuselkrankheit do not describe the disease which they discuss or their descriptions are such that no potato disease can be identified with any degree of certainty with these descriptions. Practically in all cases where the descriptions make possible the recognition of the disease the latter is usually the disease known at present under the name of „streak" or streak plus crinkle or mosaic. With exception perhaps of Schacht's description of Kräuselkrankheit there is no reason whatever to suppose that the older writers on curl, Kräuselkrankheit or frisolée have been using these names for designating the leaf-roll disease of potato. The first reliable description of leaf-roll is the one of Appel in 1906, while the first reliable descriptions of streak under the name of curl, Kräuselkrankheit, and frisolée are over one century older.

The writer is greatly obliged to the staff of the libraries of the Landwirtschaftliche Hoch Schule Berlin, the Biologischen Reichsanstalt für Land-und Forstwirtschaft, Berlin-Dahlem, the Landbouwhoogeschool te Wageningen, to Mr. Cotton of the Kew botanic Gardens and to Mrs. N. L. Alcock of the Patho-

1) For reasons which can not be discussed here and which are given in writers first paper on this subject, preference is given here to the name „stipple-streak" in designating the disease known now under the name „streak".

logical Laboratory Harpenden, England, for their valuable help in gathering the literature and to Prof. Quanjer for reading and criticising the manuscript.

FIRST PERIOD. 1775—1900.

About 1775 there appeared in England and on the continent of Europe a peculiar disease on the potato plant, which expressed itself in a stunted and dwarfish growth of the plants, curling and spotting of their leaves and stems and a marked and sudden decrease in the yields, so that in many localities the farmers had to give up the cultivation of this plant or the then favored varieties of same. The plants attacked by this disease bore so distinctly the stamp of „degeneration" that from the very first recorded appearance of the disease until the present moment the idea of „degeneration" „running out", „ontaarding", „Ausartung", „Abbau", and„senility"has been the dominating thing both in describing and explaining the nature and cause of the disease.

During the following few years after 1775 the disease appeared almost in an epidemic form and gained in destructiveness, so that it soon became the subject of the day in all countries concerned: the practical man, the man of learning and the governments were deeply concerned in the sudden appearance of so destructive a disease, which threatened the culture of the potato plant. Learned societies and governments, local and national, did offer numerous prices and encouragement to those who would discover the cause of and remedy for the destructive disease of so useful a plant, which people in those days considered as God's great blessing and their only assurance against the then not uncommon hunger years.

Indeed in some localities special measures were taken for preventing the introduction and spreading of the disease. From this period and up to the present day this disease has never left the potato plant and we find it more or less common wherever potatoes are grown on a larger scale.

In 1779 an anonymous writer described this disease in Germany as follows: „As soon as the plants show above ground, they become curled, remain stunted, part of them disappear entirely, others remain growing but never blossom, or produce only few blossoms, which fall off soon after and never form berries. They set no or only very small tubers, which are as hard as stones and unfit for eating. When planted they give rise to plants that are not always attacked by the disease. This trouble appeared first only on the white Speisekartoffeln; the Red and

large English Mastkartoffeln were free from it. In the year 1779 practically all white potatoes were destroyed, the Red-and the English potatoes were also severely attacked, while the Suppen or the so called Zuckerkartoffeln remained free from it".

Upon pulling out one of the infected plants the writer saw a distinct wound at the base of the stem next to the seed tuber, this he took for insect injury and expressed the opinion that the cause of the disease must be some insect.

As an answer to the above there appeared shortly after in same periodical a second anonymous article in which was expressed the opinion that this trouble is nothing else but a degeneration of the potato-plant, resulting from the continuous asexual propagation of same. As a control measure he recommended the renewing of the varieties from seed.

This opinion, which was expressed almost simultaneously also in Egnland and in other parts of Europe, has persisted more or less until the present date, in spite of the fact, that it was shown very early that plants produced from seed are as much subject to the disease as plants produced from tubers.

Müller in 1780 read a paper on the degeneration of potato at the meeting of the Kurfürstlichen Ökonomischen Gesellschaft at Lautern. This paper we have unfortunately in abstract form and it seems that the abstracter has missed some of the important points. Here follows his description of the diseased or degenerated plants: „In spring at the coming out of the potato plants and during the first period of growth the potatoes promise a rich crop, but as soon as the plants reach their full development and just before blossoming some of the vines wilt suddenly, the foliage grows poorly, etc., some plants send out flowers but prematurely. At this time the seed tubers are full of fibers and sprouts, and are unusually watery and their interior rotten, most of these seed tubers rot completely soon after. Such plants give later in autumn few and much smaller tubers. Such tubers are easily recognized by their light and smooth skin, while the healthy tubers have a rough and brownish red skin." Müller is of the opinion that the continuous asexual reproduction, unripe and too large seed-tubers, are the cause of the disease and recommends renewing of the varieties. Only small and ripe tubers, also tubers from uninfected regions should be used for seed. He states that around Donnersberg the potato does not degenerate and that seed from there gives good crops for some years, then it also degenerates, so that the seed should be renewed every few years.

Spring in 1781 advanced the idea that the degeneration of the potato is the result of crosspollination of the common potato by the Viehkartoffel, a less desirable potato variety used only as animal food.

Van Bavegem showed in 1782 conclusively that the degeneration of the potato which results into dwarf and curled plants is not, as was thought by some, due to insect (worm) injuries and that it lies in the tuber itself, and is the result of the fact that the European climate differs from the climate of America, where this plant is native. As control-measure he recommends therefore, the production of new varieties from American seed. His description of the disease is so short that it is not certain what disease he actually had under eye.

Simon published in 1782 what may be considered as one of the best works on the degeneration of potatoes written before the end of the eighteenth century. He describes the disease in detail as follows:

„From externally healthy tubers there grow out in infected regions on all kinds of soil and in all years more or fewer plants, whose appearance is such that even the most unexperienced person sees that there is something wrong with them. The stems of such plants differ from the other well known varieties in that they have an indistinct brown color or rather a mixed brownish green colour. Such stems which represent the first degeneration are always unbranched and in general the whole plant is from the very time of appearing above the ground smaller and remains behind the others in development.

The leaves are not smooth on the upper side as those of the healthy plants, but they are rough, curled, sickly, irregular and shrunken. They do not stand away from the stem and on well proportionate petioles, but stand close to the stem. The color of same is not brownish or darkgreen, as the leaves of the well known potato varieties, but a peculiar mixture of those colours, so that there are brownish green, light and yellowish green spots." Speaking of the general abnormality of the stems he says: „One finds often that the pith in them is also rusty and dried up, and this even in the young sprouts. As result of this there appear the small, and miserable plants, which become yellow early in fall and die at a time when the most rapid tuber formation takes place. It is no wonder then that the tubers of such plants are few in number and remain small, often only two, never more than three on one vine and are unwholesome for consumption. Even the color of the skin of such tubers is

different, it is partly brown, partly light yellow on one and the same tuber, and often the two colors run uniformly into one another."

He distinguishes three groups of this disease: „The first group consists of plants which resemble the plants described above and represents the first degree of degeneration (He means the highest degree of degeneration). This group of plants never comes to flowering. The cause of this lies in the very much destroyed organisation of the plant, which makes it impossible for such plants, which die early to come to flowering.

The second group consists of plants coming from tubers of the first group and is the second generation of this degeneration. This group consists of stronger and more yielding plants. Instead of the unbranched stems of the first group they have stems with some secondary branches. Color and form of the leaves is same, yet some of them may have a healthier color..... A small portion of these plants may flower. Most of the degenerated plants belong to this group" In reality the first group of plants should come from tubers of plants of the second group and not as Simon thinks.

„The third group consists of still less degenerated plants which resemble closely the normal ones. They differ from the last in that their leaves are smaller, curled and stand closer on the stem. The stem is not wholly brown," (i.e. it is striped.)

According to Simon the first cases of degeneration in potatoes in Germany were noticed at the time (1770) when the so called Viehkartoffeln were introducced. Before that time, he states, the disease has never been seen. The more common the growing of this variety became, the more common became also the disease among all other varieties, with the difference only that in some varieties the disease appeared more and spread more rapidly, in others less so. Localities where this variety was not grown remained free from the disease for a long time after, until at last with the general introduction of this variety the whole country did get infected.

The cause of the disease he attributes to the cross pollination of the ordinary potato varieties by the Viehkartoffel. Here is the key for understanding Simon's work. The Viehkartoffel and the other then commonly grown variety had a different color, one was light green, the other brownish green. The diseassed plants which are striped and spotted with brown spots or, according to Simon, represent a mixture of the two colors, he took for hybrids.

Through numerous observations Simon came to the conclusion that wherever the Viehkartoffel was planted in the neighbourhood of other varieties the latter degenerated.

The Viehkartoffel which has been introduced on the continent of Europe in 1770 is called also: Amercan, Wild, New Engländer, etc. It is characterized by a more robust and coarser appearance.

That Simon probably had to deal with stipple-streak is shown by the fact that the diseased plants were stunted, dwarf, stems unbranched with rusty pith, curled leaves and short petioles, brown and green colored; by the early dying of some plants, and the partial browning of the tubers.

Arthur Young in 1784 reports that some potato varieties are curled, others are not, but does not discuss the disease.

In 1783 there appeared on the potato plants in Vogtland (Germany) a disease which decreased their yield to one third and even to one sixth of the normal yield. Ackermann writes of this disease in 1784 that: „The summer of 1783 was in Vogtland so hot that most days there was visible in the air a thick fog. All crops suffered from the drought but the potatoes suffered most. Most of the tubers were hollow, weak, spoiled and unwholesome. Many of the eyes of such potatoes were black and when the tubers were boiled they could be taken out in form of a half pea. The healthy tubers had a changed appearance, their surface was not smooth as usually, but rough and ruptured, when boiled they were not starchy but soft and watery and therefore difficult for digestion."

At the same time he observed an other disease which has been seen in single cases for ten or twelve years before, but this year it was especially severe: „As soon as the plants appeared above the ground they were very much different from the other plants. They had a lighter color, were dry, weak, the leaves much farther from each other on the stem, the leaflets much closer on the petioles. Though the plants continued to grow, yet slower, they did blossom, yet much less, and seldom formed fruit. The small, hard, scabbed and internally hollow tubers had a poor taste." He attributes this trouble due to a red headed larve with hard shell, which according to Appel (1907) may have been the larve of *Eumerus lunulatus*.

When we exclude the hollowness of the tubers, which is not this of the large tubers but of small tubers and consisting of holes and gangways made by the above larve, which is much more common in dry than in wet years, we cannot but

recognize in the two diseases described by Ackermann the stipple-streak disease of the potato plant as seen on the vines and tubers.

In 1788 came out the first edition of Anderson's [1]) essay on „the disease called the curl of potatoes". This essay, which according to Anderson was written in 1778, is a remarkable document. In a concised form and most exact and critical language, supported by sound arguments Anderson tells us in only few pages what he knew and thought of the cause and nature of the curl disease of potatoes and what Anderson thought and knew regarding this disease, as will be seen from his paper, cited here in extenso, does not differ materially, from what now is known and thought of this and related diseases of potato.

Anderson's essay written in 1778, consequently being the oldest paper on this subject, is the most complete and most valuable work ever written on this disease, excepting perhaps very few of the most recent works on same subject. It can safely be considered as an up to date summary of the entire literature on running out diseases of potato. This compact and businesslike paper gives also ample evidence that its author must have been a thoroughly scientific minded person and a most keen observer. [2])

Here follows Anderson's work, the italics are mine:

„Potatoes are subjected to one particular disease, the curl, which it would be improper for me altogether to omit, and though I may say little positive as to the cause of this disorder, a good deal may be said on the negative side of the question; which, as it may possibly lead to future researtches shall here be added.

The only thing that seems to be positively certain with regard to this disorder, is, that it was scarcely, if at all, known till very lately, and in particular that it was not known in the northern parts of this island till a very few years ago (I myself had never seen it when the former parts of this treatise were written) when, there is great reason to believe, it was introduced by means of seed potatoes, imported from the South country, and *it is at this moment much less frequent in the Northern and remote parts, than in the Southern and more commercial districts of this island.*

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1) James Anderson L. L. D., F. R. S., F. S. A., of Cotfield near Leith.

2) The letter with which Anderson sent his paper to the Bath Society, dated Nov. 28, 1786, in which he emphasized the importance of research work in agriculture and which was published as an introduction to his paper, will interest every scientific worker.

From this single fact, several corollaries are deducible, which entirely overturn some theories that have been formed to account for this disease. It has been supposed that nature, fated as it were by having long produced this plant in a climate that was not deemed congenial to it, had become so far exhausted as to occasion this disease. *But if so, the more Northern parts of this island, where the climate is the most unfavourable, should have been soonest affected by it.* It has been further supposed, that potatoes that are frost-bitten (the bulbs are here meant) before they are properly housed, occasion this disease in the plants produced from them; but *the curl is least known in those districts were the potatoes are most liable to this accident.* It has been said, that potatoes which are taken up before they attained perfect maturity, infallibly became affected with this disease; but *in some cold mossy soils, and exposed situations, where the potatoes must often be taken up while they are yet in a state of vigorous vegetation, this disease is scarcely known.* It will not be imagined I mean to insinuate that such situations would preserve from the disease, when once introduced in other places around, for that, without doubt, is not the case.

It has been further alledged that such plants as have been lately obtained from seeds, properly so called, are entirely free from the curl. But I have a very striking proof before my eyes at this moment, that this is not the case. *A large field which was planted with potatoes the third year from the seed, has more than one half the plants curled; while another field near it, raised from potatoes that never were, that we know of, produced from seeds in the country has scarcely one curled plant in the whole.*

It is by some alledged that the soil or season occasion the disease, but *that this is not the case is also plain from the state of a field now in my neighbourhood. Several ridges in it, that were planted with potatoes obtained from one particular person, are very much curled, while the remainder of the field, which was planted with potatoes of the same sort, obtained from a different person, is not at all infested with that disease. In this case the soil and climate were the same (for the ridges were intermixed with the others) but the crop extremely different.*

In the last example it is plain, that *the disease depends entirely on the nature of the seed; and it seems to me highly probable that the curl in potatoes, like some hereditary diseases among animals, if once introduced, vitiates the prolific stamina, so as to be perpetuated as long as the infected breed continues to produce others.* But this is hazarded merely as a conjecture. Are there any facts sufficiently authenticated, which prove that a plant once known to

be infected with this disease, invariably produces diseased plants? Or is it for certain known, that in any case a curled potato has been produced from a plant that was perfectly sound, and not in the smallest degree affected with that disorder? Clear proofs by experiments made with the utmost caution are here wanted, and not the result of random observation.

In considering these questions, and comparing them with phenomena already known, it seems difficult to decide which way the probability lies. On the one hand, seeing this disease is, or at least most certainly was, entirely unknown in many large districts where potatoes have been long cultivated, *it would seem to favour the opinion that it only originated from infected seed*: — *on the other hand, it is asserted as a well-known fact, that fields which have been planted with seed that was in the former year very little if at all affected, have been known to produce plants the succeeding year, almost entirely of the curled sort.* Should this fact be proved, it would seem to favour the opposite hypothesis, but even here, we shall soon see reason to judge cautiously.

Infectious diseases in the animal creation may be communicated in two ways. One class of disorders can be communicated only by descent from parent to child, and can never be communicated by juxtaposition; another class of diseases can be communicated merely by juxtaposition, and not at all by descent of blood. Does such a distinction as this prevail among vegetables? Has any experiment been recorded, which proves that any particular disease among plants can be conveyed by juxtaposition only? Is not the smut in wheat of this class? May it not extend to others? May not a few infected potatoes in this way, if mixed in a large heap, like a subtile leavening principle, infect the whole? Experiments are here much wanted.

But I am far from alledging that, though it were an established fact that potatoes had been known to be much more infected with the curl, than those from whence the seed was obtained had been in the former year, it would either prove that the disease might originate from other causes than contaminated seed, or make it certain that besides direct descent the disorder could be communicated merely by juxtaposition. For though it should so happen, that the disorder could be communicated only by direct descent, the fact abovementioned might possibly happen in this way. It is well known that potatoes affected with the curl, seldom produce bulbs of a size nearly equal to those of the same kind that are sound. This being the case, should one man, from among the heap of those potatoes which were only in a small proportion affected with the curl, select

only the small potatoes for seed, and otherwise dispose of the larger ones, it is obvious he must thus preserve almost the whole of the curled sort for seed, and very few of the sound; and the potatoes raised from this seed must of course be much more infected with the curl, than the parent potatoes were, from which the seeds were obtained.

On the other hand, should another man pick out from the same parent stock only the very largest bulbs he could find, he would probably have scarcely one curled plant in the whole field. Thus might the seed from the same heap prove to be, in one field entirely free from the infection, and in the other altogether diseased. Men are in general so careless in observing facts of the nature here alluded to, that we frequently meet with inexplicable phenomena like what we have here supposed. But till these particulars be fully investigated, *it would seem to be, from many considerations, the safest plan to select only the largest bulbs for plants, for as there is reason to think the disease proceeds in all cases from the seeds planted, and as the infection must certainly be less virulent in the plants that have been least previously infected with it than others, and as no large potatoes are produced by plants which are strongly affected by this disease, these ought surely to be chosen for plants in preference to others. This I know, that I never yet have observed a curled potato among those I have obtained from large potatoes planted whole.*

Should it be found that this disorder, like the small-pox or measles among mankind, can be communicated by juxtaposition only, in that case it would be prudent to select the large bulbs at the time of taking them out of the ground, putting them all in one heap then, without ever letting them touch the small, and thus keep them entirely separate. *By these cautions, accompanied with roguing the potatoes as soon as they are fairly above ground, (that is, pulling out all those that shewed the smallest symptom of this disease) it seems to me probable it might be in a great measure, if not entirely, avoided.*"

„The greater part of the essay was written in the year 1778, a few observations having been added, which are distinguished from the original essay by being included within crochets (thus)."

Marchall in 1788 attributed the cause of the disease he called „curled tops" due to „too long a continuance of declining varieties" and states that „fresh varieties raised from seed, are not liable to that disease". He writes further that „Plants procured from the Morelands remain free from it in the Vale, the first year: but being continued, become liable to the disease."

„The disease of curled tops is seldom obvious at the first coming up of the plants: but attacks them as they increase in size; the entire top becoming dwarfed and shriveled as if affected by drought, or loaded with insects; they nevertheless live, and increase, though slowly, in size, but the roots are unproductive".

„Where the attack had been partial, weeding out the diseased plants as they failed, is said to have had a good effect. And it is said, the Morelanders got rid of the disease through this means".

Mordaunt in 1790 speaking of „curl" states that „the leaves curling to a very great degree; when that happens you find only one or two small roots not worth the expense of taking up". As cause of the disease he considered a milliped, which bored into the potato stems.

In 1790 there appeared in England simultaneously three papers on „curled potato" which were presented to the Society of Encouragement of Arts, Manufactures and Commerce for the prize offered for the best paper on this subject.

William Hollins the author of the first paper writes that: „The curl in potatoes is a disease which admits of three different stages or degrees:

1st. The half curl,
2d. The curl.
3e. The corrupted.

1st. The half curled plants have leaves somewhat long and curled only in a moderate degree. They produce a tolerable crop if the summer be not very dry; but if otherwise the potato will be small and watery.

2d. The completely curled plants are seldom more than 6 or 7 inches high, they soon ripen and die. The potatoes are generally smaller than a nutmeg, of a rusty red colour and unwholesome as food.

3d. The corrupted potatoes or those in which the vegetative power is nearly destroyed never appear above ground. The seed may be found at Michaelmas as fresh to appearance as when it was set with a few small potatoes close to it".

The cause of curl he attributes to the manner in which the seed has been raised the preceeding year: too rich soil, earthing and manuring of the fields: „By earthing and manuring you will only raise large crops of large potatoes perfectly good as food but imperfect as seed".

William Pitt, the second author, recommends on the other hand the breeding of new varieties and advises the potato grower „to secure his seed from as perfect a plant as possible and by no means to use seed of a worn and degenerated plant."

John Holt, the author of the third paper, contrary to the first two writes the following on curl: „The cause of this disease, as far as I can judge does not arise from peculiarity of soil, variety of manure, difference of season, dry or moist, the cause, therefore, whatever it may be it should seem originated from the seed which when once infected I imagine is incurable and the disease or curl appears to be nothing more than a total degeneracy of the plant by being worn out by want of change of seed upon the same soil with probably some other causes cooperating". In his second article on same subject he states that fresh seed from the moor lands gives as good results as potato seed brought from Scotland.

John Billingsley writing in 1792 on the culture of potatoes is not sure of the cause of curl of which he says: „It seems enveloped in an impenetrable mystery". Potatoes brought from Dumfries were never curled the first year. „Perhaps the second year a few would be curled, but beware of the third, for be it assured, let your soil or manure be ever so good, almost all will be curled the third year, if planted in the same soil and neighbourhood".

Parmantier, whose activities in connection with the introduction and spreading of the potato plant in France are well known, speaking of the diseases of potato in 1793 says: „But the disease which especially attacks the potato, known in the district of Lyon under the name frisolée and in Flandren under that of pivre, is characterized by the mottled brownish green stems, wrinkled, weak, curled and standing close on the stem with yellowish spots and of a peculiar texture leaves".

Buchan-Hepburn writes in 1794 that the curl disease of the potato, which he does not describe, has not been observed in the East Lothian county until about 1778. In 1780 it was very destructive in Lancashire, „but it was not till 1784, that it was feriously (furiously) felt in this country, when it seemed to threaten the total extermination of the plant. The only remedy is change of seed. It is somewhat singular, however, that this distemper is unknown in the higher districts of this country, at an altitude of about 400 feet above the level of the sea". „The seed brought from that district, may be planted for two

years; but if continued longer, the curl takes place, and the 3d., and every subsequent year, it grows worse and worse." Same fact was observed also by Tuke and Holt.

Buchan-Hepburn thinks that the reason for this lies in the fact that in the higher and northern regions the potatoes never ripen fully and are usually harvested, on account of the early frost, while still not fully ripened. He comes then to the conclusion that the potatoes for seed, where curl is present, should be harvested earlier than the rest of the potatoes in order to avoid the disease.

„The renewing of the seed by raising it from the apple, has been repeatedly tried in this county, and it has always proved ultimately unsuccessful; that is this new seed in the course of a few years became curled".

He reports also that the „Yam" or „Surinam potato" which is a very prolific and unusually late variety has never hitherto been injured by the curl. This variety which is a less desirable one and was commonly used as animal food is stated to have been brought by a sailor from America (Löbe) and has been known in England ever since 1711. Same variety was introduced into Germany under the name of „Viehkartoffel" in 1770 at the time of the great food scarcity and has been considered as the cause of the Kräuselkrankheit in Germany.

Kirkpatrick in 1796 while not describing the disease recommends as control measure against curl the annual change of seed. He tells us also how it came about to discover that seed potatoes brought from Scotland to England, where the curl was causing at that time great damage, gave the first year curl free plants. About 1776 at a time when potatoes bore a high price in England, a sloop load arrived from Scotland at Liverpool late in the spring. These potatoes were used for planting and gave such good and free from the curl crops, that many sloop loads have been annually imported since that time for planting: A practice which has persisted for over one hundred and fifty years and which is being used now on a large scale.

An anonymous writer in 1798 saw the cause of curl in the growing of potatoes from the seed of the potato berries. He recommends as control measure the destruction in the field of all curled plants as soon as they appear above the ground or as he writes: „when they are about three inches high". He states also that no curl has been seen on the Red potatoes, which he attributes to the fact that this variety is never grown from the seed. He personally planted the seed of this potato and got

some curled plants. May not this be an indication that resistant varieties can be obtained through breeding. This author states also that no curl has been known up to about 1750 and that it appeared first about ten years later when the breeding of new potato varieties from the potato berries was introduced.

Stockmar in 1801 not only did make observations in connection with the degeneration or Kräuselkrankheit of potatoes but actually tried to establish in an experimental way the cause and nature of this malady. Speaking of the marked decrease in yields due to it, he says: „At the same time one notices that a large portion of the plants does not have any more the healthy appearance as before, that a large number of them are not only unnaturally curled and withered as if the mildew has attacked them, but that their stems are single and unbranched, while the healthy plants have many secondary branches. These not only sickly looking but actually sick plants when pulled out are easily recognized by the rust like spots, which often reach as far as the pith of the stem, such plants seldom remain alive until harvesting, but usually wilt and die already in August.... of which later not even a trace is to be seen." He also reports that wherever the Viehkartoffel is planted next to Red potato (the commonly grown variety of those days) the latter is usually more attacked; in such cases the disease not only does spread more rapidly, but it becomes so common that the farmers did consider it as a punishment of God. The Viehkartoffel it self, he states, as was noticed also by Simon and Ackermann, does not suffer from the disease and even though much poorer in quality it did gradually replace in most localities the ordinary varieties, both red and yellow, which did suffer much from the disease.

The cause of the disease he sees also in the cross pollination of the common varieties by the Viehkartoffel: The diseased plants are nothing but hybrids of the first and second variety, including the tubers. He also makes the statement that in localities where no Viehkartoffel is grown there is also no disease.

Stockmar made at last some experiments to establish the correctness of the above hypothesis. For this purpose he took tubers from the susceptible potato varieties from localities where the disease was not known, one portion of these tubers he planted away from, the other portion next to Viehkartoffeln. The first year all plants remained healthy. The second year he planted the tubers of the potatoes that have been next to Viehkartoffeln away from such potatoes and planted again other

healthy potatoes near the Viehkartoffeln. Of the potatoes which the first year have been next to the Viehkartoffeln he writes: „After the first leaves had hardly appeared above the ground I saw what I had suspected: more than half of these plants were curled, while the potatoes grown the previous year away from Viehkartoffeln, also those which this year are next to the latter did not show even the slightest symptoms of curling." The curled plants he considered, therefore, as „hybrids": the red potatoes being pollinated by the Viehkartoffeln. There can be, however, no question of hybrids, as Stockmar used not the berries but the tubers of the „crosspollinated" plants.

He made another experiment: Some plants standing next to Viehkartoffel plants he marked and removed their flower buds before flowering, others of these plants he let flower. The following year all of the first gave healthy plants most of the second gave diseased plants. This he took as a second confimation of his hypothesis. Seeds from the berries of plants standing next to Viehkartoffeln and which he considered as infected produced healthy plants the first and the second year, while the tubers of same plants gave diseased plants. He concludes then that the seed itself is not affected by the crosspollination and that only the tubers are affected. As control measures he recommends: 1. Growing separately the two kinds of potatoes. 2. Using seed for raising of new plants, which also get infected if planted next to Viehkartoffeln. 3. Only tubers from healthy plants should be used for seed. 4. Using seed from uninfected regions.

Thaer (1801) observed in 1790 in West Germany the disease then called „curl" in England. Of it he writes: „When the potato plants reach their full development and just before flowering they become suddenly curled, wilt and dry up. The yield is then very small. The real cause of this disease has not been found yet. It is certain however that the cause does not lie in the soil, in the cultural methods or in the climate, but in the seedtuber itself. As soon as this „curl" appears on some plants there must be brought seed from somewhere else, otherwise the following year it will become much worse. It is highly probable that some insect which is too small to be seen and which lays its eggs in the tuber is the cause of this disease. It has been thought that the disease can be controlled by growing potatoes from seed, but the seedlings are attacked even more. Large and healthy tubers from localities where the disease is not known did always remain healthy. For that reason many people order

such tubers every year." In the 3d. volume of his classical work which appeared three years later, speaking again of curl he applies to it the name Kräuselkrankheit. Here he states also that the white varieties are less attacked by the curl.

An anonymous writer in the Farmers Magazine of 1802 recommended the use of the „little" or aerial potato tubers for seed as control against curl.

Höse in 1804 writes that roguing of all infected plants did help in controlling the Kräuselkrankheit.

Pryce in 1802 agreeing with Billingsley that the cause of the curl disease of potato is „involved in impenetrable mystery" writes of it that „Like him, I have found that potatoes of same sort, kept in the same manner, planted at the same time, in the same soil, and in every respect alike circumstanced, have produced part of the crop curled, and part not curled; — and like him I have found two shoots from the same set, of which the one was curled, and the other healthy".

„After much diligent observations and enquiry, I had reason to believe that the disorder did not arrise from degenerated or defective seed; and as it is certain that the plant is diseased when it first appears above the ground, I concluded that the germ or shoot must receive an accidental injury, between the old set and the surface of the ground". This injury and therefore the cause of the disease he atributes to insects.

„In northern aspects, or on cold damp land, the curl is less frequent than on warm or sandy land, where insects are more numerous: and it is pretty generally acknowledged that seed potatoes, procured from damp morassy lands, or those from more cold or northerly climates, or situations, will not curl the first year after planting".

„The potato, it is said, was introduced into this Island near two hundred years before the curl made its appearance. That this vegetable should, after such a period, suddenly degenerate, and that the soundest seed should now degenerate in two or three years, seems not very consistent with sound philosophy".

„It may be remembered that about fifteen years ago, when the curl was most fatal, there was a general alarm for the consequences that might arrive from insects. Almost every bush teemed with their nests". This fact is here recorded as in the light of recent investigations it seems quite evident that there exists a close relation between the severity of the running out diseases of potato and the amount of insects in the different years.

In 1802 a correspondent of the Farmers Magazine attributed the cause of curl also to various insects and even to „minute animalculae", which attack the underground and aerial portions of the potato plant. „I think, he writes, I have also observed, that these insects prefer one potato to another. They will hardly touch a Yam (an undesirable potato variety)". There is considerable truth in the last statement and taken theoretitally it will be possible to breed insect-resistant potato varieties, just as has been done with other plants. Should this actually be possible and if it is true, as is generally thought now, that the degeneration diseases of potato, at least most of them are transmitted only by aphids, then the breeding of aphid-resistent potato varieties will be also an effective control measure against this group of diseases.

Dickson, R. W. in 1805 discussing the curl disease of potato, without describing it, states that „most of early authors considered it in general as originating from distempered seed, which caused it to appear in the crops wherever it was made use of". Reviewing the then prevailing suppositions as to the nature and cause of the disease he seems to be inclined to think that insects attacking the seed tuber may be the cause of the disease," as it was found that, from a potato planted in a field as seed, there proceeded four stems, two of which were weak and delicate, having their leaves attacked with the disease, while the other two were in a highly vigorous state, and their leaves fresh and free from the curl. On the root being taken up, it was discovered that all the part from which the curlleaved stems proceeded was excavated, the substance being wholly consumed by insects." It is more than evident that partial injury of the seed tuber, especially after it has germinated can not be the cause of the above conditions. He adds further: „Sometimes it is, indeed, supposed, that the disease may be caused by the leaves only becoming the pray of numerous minute animalculae, but that the general cause is in the seed (the tuber) itself being consumed" (by insects). This suggestion that the curl disease is caused by a bacterium in view of the fact that at that time nothing was known of the pathogenicity of bacteria cannot be taken too seriously and is here recorded only for the sake of completeness.

An other opinion concerning the cause of curl was that it lies in the season and that „where the spring is late, cold, and frosty and the potatoes set at an early period, the crop is mostly injured by the curl; while those that are planted at a

later period, and which are not so much exposed to the effect of cold and frost in their early growth, are more free from the disease." This agrees with the conditions under which the epidemic appearance of stipple-streak in 1921 took place among the early potato varieties in North Holland. Only further observations, however, can show whether this really stands in some relation to the disease. Whether the disease Dickson discusses here was really stipple-streak or some other of the diseases related to it is not at all certain from his discussion of curl.

Stating that „though many of the different causes may operate in producing a tendency to the production of curl in potato crops, they do not any of them seem fully sufficient to account for the disease in a perfectly satisfactory manner", and that „further investigations into the nature of the disease is still wanting in order to fully elucidate its cause", he adds: „That something of this nature takes place, seems evident from the circumstance of only some of the plants being diseased, while others nearly adjoining them are in a healthy and luxuriant condition".

Dickson remarks also that „the general experience of cultivators has fully shown that the crops of such potato sets as have been brought from high cold climates (Scotland and North England) where the potato scarcely ever arrives at that state of perfect maturity in which seed is produced, is rarely if ever affected with the curl for the first year".

Howdeniensis in 1805 attributed the cause of curl due to the „difference in temperature" in the pits and in the field.

Baron Hepburn [1]) in 1808 assures us also that up to 1778-1779 the curl disease of the potato plant has been unknown in Scotland or that it has been present in a very small amount, „too trifling to merit attention". The first case of curl as a serious and alarming calamity was observed in the autumn of 1780, „it so infected the crop of potatoes in Cumberland as to threaten total exclusion of the potato from the husbrandry culture of that country". In the year 1783-84 the curl made again a general and alarming appearance in the low part of Scotland. Contrary to former writers he states that potato produced from seed remain free from curl during the first few years. He repeats again his former observations that curl is common in the low part of Lanarkshire and Renfrewshire, but it has been never seen in

1) Formerly Buchan-Hepburn, G.

the parish of Strathaven (Lanarkshire), in the mountains of Lammermoor, nor generally at an elevation of 400 ft. above the level of the sea. Seed brought from these regions down to the coast might be safely trusted for two years.

Thomas Dickson in 1810 discussing the curl of potatoes writes that of all the different theories regarding the cause of curl the one of Baron Hepburn (1794) that the curl is the result of an overripening of the tubers, is the right one. As control measure he recommends later planting, earlier harvesting, and preventing the plants from flowering.

Shirreff in 1810 taking for granted that all plants do eventually die considers the potato curl therefore, as a state of senility and recommends the raising of new varieties from seed.

Crichton in 1814 after numerous „experiments" comes to the unique conclusion that „wherever the seed stock is carefully pitted and not exposed to the air in the spring, the crop has seldom had any curl, but where the seed stock is put into barns and outhouses for months together, such crops seldom escape turning out in a great measure curled".

Putsch and Bertuch in 1819 described the Kräuselkrankheit as follows: The plants attacked by this disease have an unusually miserable appearance. The stem is unbranched, brownish-green or striped, covered here and three with rust spots, which penetrate as far as the pith, so that the latter is no longer white but rusty and sometimes even black. The leaves are not smooth on the upperside, as those of the other plants, but are rough, wrinkled, curled, weakly and shrunken; do not stand away from and on well proportionate stems, but stand close to same. Their color is not brownish or dark-green, as the leaves of the healthy plants, but have at the same time a peculiar mixture of both of these colors, so that there are on them brownish, light green and yellowish green spots.... Even the skin of the tubers is different. It is partly brown, partly pale yellow on one and the same tuber, and often both colors are intermixed. Experiments have shown that some varieties are more, others less susceptible to this disease; that the potatoes in the mountains are less subject to it than those in the plains, and that the round and long red varieties suffer more from it than the white varieties. The disease passes over with the tubers to the next generation and only after careful cultivation (roguing) it will not disappear before the fourth or fifth generation."

In Schnees landw. Zeitung of 1828 an anonymous writer

repeats the above description of this disease and reviews Hollin's and Dickson's papers on same subject.

Wiegmann in 1839 placed the Kräuselkrankheit of the potato in the group of diseases which he calls „diseases of the respiratory system" and considers it as a „Hautausschlag": „The Kräuselkrankheit of potatoes should not be mixed up with the similarly called disease of the peach tree and apricot, it is the result either of cold nights or poor soil. Cold winds and cold nights following after warm days weaken the potato plant originating, from a warmer climate, which is even less able to resist the above injuries than the first named plants. The leaves are attacked by a black rust, curl and fall off, the tubers robbed of the intimate connection with the leaves, which nourish them, remain behind in their development and have an inferior taste."

Berchthold in 1842 repeating Ackermann's and Putsch und Bertuch's descriptions of the Kräuselkrankheit writes as follows concerning the eye disease of the potato, which he considered as a distinct and different disease: „Plugging of the eyes is the disease which appears on the surface as a black spot, from which cylindrical black bodies, 2—3 lines thick or round, resembling the mass of the potato but somewhat more compact, press towards the heart of the tubers. Some of the destroyed and blackened eyes can be taken out in form of a black pea". He also states that the round and long red varieties are more susceptible to the Kräuselkrankheit than the white varieties, and that the disease is more severe in the plains than in the higher regions. It is transmitted with the seed tuber and disappears when careful selection is practised after four or five generations. Of the cause of the disease he is not certain, but states that „there appear practically no diseased plants when tubers from diseased plants are laid in holes in which have been placed some wood ashes and salt and over them are spread some wood sawings". At the end he mentions the old hypothesis that the disease is nothing but degeneration of the plants due to senility.

Martius and Löbe in 1842 and Münter in 1846 describing the then epidemic appearance of the Phytophthora disease gave also an up to date review of the literature on potato disease, including the Kräuselkrankheit.

Thompson (1845?) planting potatoes on a very rich soil and the season being unusually favorable, he expected a rich crop,

but he was „much disappointed to find that the braird was weakly and soon showed symptons of curl. This increased, and though few of the plants perished, nearly the whole were unhealthy .... wherever the disease had made a decided impression on the set, the stalks of the plant were marked with brown streaks and patches, and evidently showed that the juices which they were conducting from the set were vitiated and noxious. The part of the stalk to which I directed mij attention was that underground, in which it was easy to trace the progress of the disease, from their being white and nearly transparent. Wherever the top was curled I found the stalks unsound and the set diseased. In some cases the disease carried the day, and the set reaching an advanced stage of decomposition, and the stalks below ground became quite brown, the top died away. In a subsequent season (1844) most of the sets attacked perished, but on this occasion a very great majority of the plants threw out strong roots, and finding an abundant supply of food, maintained a constant struggle with the disease, and eventually yielded a good half crop. A few green healthy plants stood prominently out amongst the brown half-withered tops of the rest". These plants he found to be of a different variety (Cheshire white). From the above he concludes that the curl, dry-rot and wet-rot are one and the same disease, and that curl represents a mild attack of the disease, which when „violent" destroys the set before it can germinate. The following year he planted again part of the above seed, but somewhat later (8th of June) and obtained a perfectly healthy crop, whereas plants from an other sample of tubers showed much curl and gave a failure crop. This he attributes to the fact that the first seed has been harvested earlier (2d of October). The cause of the disease he sees therefore in the „overripening" of the seed and recommends the use of unripe seed. It is certain from what we now know of this disease that the „unripe" seed or the late planting in this case could not have been the reason of the disappearance of the disease in the following generation. It is very likely that Thompson took by mistake one lot of tubers for the other. This is supported also by the fact that his intention was not at all to experiment with these tubers, but one of his crops having failed he plowed the ground and planted potatoes as second crop on same land, taking evidently as seed what had left over. The curl of the potato plant at that time was too well known in England to suppose that he had to deal with an other disease, which seems highly improbable when we consider his description of the disease.

John Townley in 1847, reviewing practically the whole English literature on curl up to date and the numerous theories and most opposing observations regarding the nature and cause of curl in potatoes, accepts Knight's teaching that „a progessive decline of the vital powers takes place in the potato, corresponding to the familiar phenomenon accompanying old age in the animal world.... the gradual alteration of the tubers is of too general and progressive a character to be the exclusive result of any external influence. It is manifestly a consequence of the declining power of the inherent principle of life.

Mr. Knight's observation that the dry and farinaceous tuber „indicates some degree of approximation to disease" is evidently well founded. The shrivelling of the aged vegetable corresponds exactly with that of the aged animal and obviously arises from similar causes". Stating that unripe tubers from plants harvested early, from late-planted plants, or from plants from northern, cooler and higher locations give curl-free plants, he writes that: „Possibly the ripe state of the tuber of an aged variety may expose the plant to attack by some animal or vegetable parasite. The stems of curled plants have been observed to be „marked with brown streaks or patches" or „rusty coloured spots", but it is not certain whether this is due to decay or to parasitic action. It is highly improbable that aphids are the cause of curl, the fact that healthy and diseased plants grow side by side being irreconcilable with their method of attack".

Gasparin in 1848 describes the potato disease called frisolée in France, which name he also uses, as follows: „The stems are conspicuous by the rusty spots, the edges of the leaves are wrinkled, the later are irregular and curled. The young plants die at a time when their growth should be most vigorous, and form but few small tubers, which have a pungent taste. Some varieties are highly susceptible to the disease. It is thought that it is propagated by planting infected tubers, which are recognized by their hardness (corkiness). This condition has been attributed due to the presence of an insect in the pith of the stem and as control measure has been suggested placing some ashes and salt in the holes in which are to be planted the tubers". This control measure Gasparin has evidently taken from Berchthold.

Stephens in 1849 states that the then well known curl disease of potatoes, which he does not describe, is transmitted with te seed from year to year.[1]

Uilkens in 1852 decsribed briefly the disease of potato which

he calls „Krol" or „Krul" as follows: The fresh color of the leaves disappears, the leaves are shriveled, the growth ceases and the plants remain small and weak the whole summer. This disease is as common as the potato disease was some years ago and does sometimes destroy whole fields. It is especially common on the variety Stoelmatten.

Schacht in 1856 describes the Kräuselkrankheit of potato as follows: „The Kräuselkrankheit appears on the leaves first in form of pink-red or violet-brown colored spots, which appear on the tips and edges of the leaflets and preferably on the top leaflets. It appears first on the upper side, the edge of the leaf curls, its wave-like undulations turn upwards. The curled violet-brown colored portions are at the same time firmer and harder than the surrounding healthy but soft leaf tissues. The Kräuselkrankheit appeared this year in the cases observed by me on the same day when the first symptoms of the potato disease in form of yellow spots became apparent.

The disease starts here as in the case of the late blight from the upper side of the leaves. No fungi whatever are present."

The above description makes it more probable that Schacht had to deal with the leaf roll disease of potato, while his illustration of same reminds us more of potato mosaic.

This single case in the whole literature on degeneration and running-out of potatoes, against which there stands a large number of much more reliable and more extensive papers on this subject, has led in recent years to the conclusion that the name Kräuselkrankheit and curl are „Sammelbegriffe" and that they do not designate a certain disease, but that they cover a number of related diseases, including leaf roll.

It is necessary to learn Schacht's ideas regarding the cause of Kräuselkrankheit in order to appreciate how little value should be attached to his work on this disease: „The cause of the Kräuselkrankheit seems to be the same as that of late blight.... Weather conditions, depressing (schwüle) storm air followed by a sudden dropping of the temperature seems to be here also the first cause of this trouble, the same under certain conditions passes actually into late blight. The portions of the leaves attacked by the Kräuselkrankheit become black and begin to rot, especially in moist and warmer weather, the well known potato fungus (*Peromospora infestans*) then established itself on them; in dry weather they (the leaves) remain for some time fresh and dry up afterwards without rotting and fungous association.... since it (the Kräuselkrankheit) is closely related to the late

blight (the real potato disease) and passes into the latter, it is therefore probable that certain conditions must favor the appearance of this form. This explains also the so common mixing up (?) of the two troubles with one another". The Kräuselkrankheit is nothing but a form of late blight, both of which are caused by a sudden change of temperature!

A more naive treatment of the two diseases, both of which were at that time almost as well understood, fundamentally at least, as now, is hardly possible, and it goes far beyond any of the eighteenth century's conception on this question. The contribution of the well-known botanical authority to the understanding of both of these diseases must therefore be considered as absolutely negative. Such an opinion held by so renowned an authority, at a time when numerous other writers were beginning to consider *Phytophthora infestans* as the real cause of late blight and who knew already that the Kräuselkrankheit is transmitted with the seed tubers, and that it has nothing to do with the disease before-mentioned, must have had a retarding influence upon the studying and understanding of both problems.

Kühn in his classical work on plant diseases describes the Kräuselkrankheit which contrary, as he states, to the Stephens' statement, that it is to be seen even in earliest development of the plants, he observed first in June. „The diseased plants are noticeable by their dwarf appearance from far away. They have not the green color of the healthy plant, the leaflets of the leaf are not only curled and wavy but the main petiole is bent down, so that the whole foliage appears curled and drawn together. The leaflets show local discolorations and at the point of bending of the main petiole there usually appear dirty brown, more or less elongated spots which did appear even on the stem, and became gradually more and more numerous. The discoloration of the cells in these spots while originally only superficial, gradually penetrates deeper, so that in such places the browning eventually penetrates into the stem, so that the pith takes on also a brown and rusty appearance. On the gradually more and more wilting leaves as well as on the brown colored spots of the leaf veins, petioles and stems I could not find any fungous mycelium, nor a fully developed fungus. On the other hand the stems did show, even in places where there were no spots, a peculiar texture, they are brittle and did break, when bent like glass. It seems to me that the cause of this lies in an unusual turgidity („Vollsaftigkeit"). Another cause of the disease was not to be seen. In some rows of plants there were

some perfectly normally developed, while the greater portion of the plants around them showed all symptoms of the disease". Kühn considers it as probable that the weather conditions may have some influence upon the appearance of the disease, but thinks that it cannot be a determining factor, and noticing that the disease appears preferably on very succulent and vigorous plants, he expressed the opinion that anything which may bring about a uniform growth and development of the plants will be a proper control measure against this disease.

In 1872 Kühn describes again the Kräuselkrankheit as before, but it seems that in this case besides stipple-streak be must have had some other disease, as well, probably mosaic, as he states that some of the infected plants at several times during the summer did recover more or less from the disease after coming of dry weather, while with the coming of rain the disease reappeared again. This as we know now is quite typical of potato mosaic. The above thing happened in such a distinct form only in one variety, while in most cases the plants of the other varieties remained sick for the whole season. Here he states that the disease can be very severe and that in some varieties over 50 % of all plants were diseased, and that large number of them died before the middle of August. He saw the disease as bad on seedlings and young varieties as in old varieties and opposes the then prevalent opinion, that the disease can be controlled by growing only young varieties and by breeding potatoes from seed. He opposes further the idea that the appearance of the disease means a degeneration or senility of the potato plant and shows that the variety Lerchenkartoffel described by Putsch and Bertuch in 1819 was then as much valued and gave as good yields as before. Same, he states, is true of the variety Zwiebelkartoffel, also described by Putsch and Bertuch. With numerous data he shows that now potatoes are yielding as much as before. In years when there has been noticed an actual decrease in yield, this has been the result of distinct potato diseases. Unquestionably, he writes, some varieties are less, others more susceptible to these diseases, but this lies in the nature of the variety and not in its age.

Sorauer in 1874 described the Kräuselkrankheit as follows: „The petioles of the infected plants are usually bent down or completely rolled, the leaflets are wrinkled and wavy, with brown, mostly elongated spots. The latter extend along the petiol of the leaf and finally over the stem. At first only the outer cells of the spots are brown, the browning extends later

into the interior tissues and in the stem as far as the pith, while the normal elasticity of the stem may change into a glasslike brittleness .... When such plants remain alive until digging they show no or only a scarce tuber formation." The cause of the disease he sees, as Kühn did, in the too heavy manuring and recommends the use only of well decomposed manure and planting the potatoes on light or well drained land and on high locations.

In 1875 there appeared again in England and on the continent in Europe, especially in Germany, the curl or Kräuselkrankheit of potatoes, which, while seen in the previous few years on single plants, appeared now in a somewhat epidemic form. Both in England and in Germany this caused a great apprehension and excitement. A stream of papers on this question appeared in both countries and there was, at least in the beginning a great misunderstanding as to the nature and cause of the disease.

As an illustration of the above may serve the first paragraph of an editorial warning in the Journal of Horticulture of June 17, 1875. p. 469:

„Warning! New potato disease.

We regret to announce the appearance of a New potato disease more destructive in its effects by far than that (the Phytophthora disease) from which the plant has suffered during the past thirty years".

In an editorial article of the Gardener's Chronicle of July 3d, 1875 this disease, now called the „New potato disease", was described as follows: „Some of the plants are throwing out new roots, and seem in a poor way to recover. In most cases, the formation of tubers is totally arrested, but in other cases, the tubers are formed and we have before us some tubers perfectly sound, and as large as a medium sized apple, which we took from a haulm that was withered and flaccid. It appears to us that the roots and the underground portions of the haulm were the first to become affected, the cellular cortical portions being the first to show signs of decay; if severely so, then, of course, no tubers are formed, but if partially so, then tubers may be formed. The leaves seem to be affected subsequently to the underground portions; they become spotted with brown spots, the colour of which is deeper on the upper surface, and by and by the whole leaf withers and dries up; the lower leaves are first affected, the tops remaining green after the lower ones are dead. Microscopical examination has revealed to us nothing but the brown coloured tissue and brown masses, consisting probably of altered protoplasm. We have not been able to

detect either fungus or insect." Destruction of all infected plants is recommended.

In same periodical and number (p. 16—17) was included a note from Berkeley on same disease. „The disease appeared, he writes, the previous years but did not attract much attention. The Early rose within four days, had flourished, wonderfully, and was producing good sized tubers, but the condition is now entirely altered, the rapidity and degree of disease depending on the comparatively decomposed set. Where the set has become deliquescent spots first appear at the base of the haulm, discoloured and crocking the haulm at once decays, as the peculiar spots appear on the leaves; where the set is still comparatively healthy no spots appear on the base of the stem, but the diseased condition is strongly visible on the leaves. I have carefully examined the leaf-spots, and though occasionally I find one or two bodies which I can refer to nothing save Protomyces, they are so inconstant that they cannot at present be asserted to be the cause or justify one in saying that the disease is likely to be propagated by spores". He states further that it may prove to be a constitutional disease and points out that it must be established first whether the disease spreads over the healthy plants and whether it differs from the „curl" which seems to be unknown to the existing generation. In a foot note he adds however: „It seems almost certain that it (the new disease) is the same disease which was formally prevalent in this country, especially in the North, where it was too well-known under the name of „curl". One singular point is that in some cases where the disease has commenced below there is an effort to make a new growth, one side of the stem alone being diseased".

Somewhat later of same year there appeared in same journal another note on the „New potato disease". In it is stated that this disease attacks only American varieties from home grown seed. All grown from seed imported directly from the United States are perfectly healthy. „In all cases, there is the arrested paralized growth, the leaves unhealthy and curled, and covered above and beneath with numerous small dark spots. A good number of the plants were lifted and the roots examined, and in only two cases had the seed tuber rotted.... At the point where the shoots grew out from the eye it appeared to be as healthy as could well be desired; but at the distance of from 1 to 2 inches from the set the stem of the foliage was rotted through to the centre, and so thoroughly was the centre rotted in some instances that it suggested the question whether the malady arose in the interior of the stem and came outwards".

Dean on July 17 of same year reports, that contrary to other observations, he has seen the disease also on plants from seed brought directly from America, namely on Thorburn's Paragon. Of the disease he writes: „this form however differs materially from any I have hitherto seen, as the haulm generally was at first robust and healthy, but within the last 10 days I have observed that the axils of the leafstocks blackened, then gave way, and eventually the whole of the foliage on a stalk fall off, leaving only a bare diseased stem. This appearance is confined to this variety only." He opposes the idea that insects are the cause of the disease.

P. Smith in 1875 observing the „New disease" of potato in England and wishing to find out whether it was present on the continent of Europe, published a paper in Germany on this subject. In this paper, discussing the recent works of Berkeley and other Englishmen on this subject, he states that the unusually dry season may have probably contributed much to the destructiveness of the disease as the plants did suffer much from the drought and some even died as result of it.

In the Journal of Horticulrture of 1875 there appeared several short notes on the „New potato disease" in which besides brief descriptions of the disease is stated several times that this disease is same as the curl of former days.

In Germany the same disease, which has been noticed in the previous years as well, attracted considerable attention in 1875 and a series of papers appeared on this subject the same year.

The editor of the Deutsche landw. Presse writes in this periodical that the variety Early Rose is the one commonly attacked and to such a degree that its growing has to be given up. The disease is to be seen on the plants as early as the second part of May. Some of the plants die soon after and send out new shoots but do never form any tubers. In this paper he includes a note from Drechsler in which the latter gives the following description of the disease: „The leaves of single vines while not yet fully developed become brown spotted, the stems become also rusty, shrivel up and in short time, 10—14 days, the whole foliage, excepting perhaps some of the stems, disappears completely." That is to be seen as early as the beginning of June. In some cases only single shoots from one hill do get infected. Drechsler could not find any mycelium or fungous spores in the infected plants.

Deetz, same year, describes under the name Kräuselkrankheit

some potato troubles, but it is not possible to tell what disease or diseases he had to deal with. He states that the leaves of the infected plants in some cases take on a pink to violet color, describes further this disease in a way that reminds us of stipple-streak and early blight, also of insect injuries. He is of the opinion that aphids are the cause of the disease.

Hallier came out in 1875, 1876 en 1878 with several papers in which he tried to explain the cause and nature of the Kräuselkrankheit of the potato plant. „The disease, he writes, attacks preferably the potato varieties with tender skin and foliage. The so far entirely healthy foliage becomes spotted with small round and black spots, which increase rapidly in number and size. At this time the tips of the leaves become yellowish and wilt, their edges curl and shrivel together, at this moment the leaves and stems are extremely brittle and break like glass when bent. Soon the whole infected shoot wilts from the top down and becomes black. The degree of infection varies considerably. Sometimes the tubers do not germinate at all or the young shoots die soon after; in other cases the shoots die shortly before flowering, or flower sparingly. It is very noticeable and differing from all other potato diseases, that often only single shoots of a seed tuber are attacked, while the others remain entirely healthy and give a good yield." The disease apparently does not spread from one plant to another. In all portions of the infected stems he finds a fine mycelium, which at first is white and later takes on a dark color. This fungus is supposed to pass from the infected stems into the stolons and the young tubers.

He distinguishes two forms of the disease. The form described above is the first form of the disease. When the tubers of such plants were planted the following year he got decidedly abnormal and dwarf plants. Some of the tubers did not germinate at all, others produced small shoots which died immediately after, still others formed unusually thick stems but they were very abnormal and bent, the petioles bent strongly downwards and so did the leaves, the edges of the latter become curled and wavy but never wilt, leaves and stems are as brittle as glass. The leaves are abnormal and die before reaching full development. The shoots usually die before long and only seldom remain alive for longer time. This dying of the shoots is usually very rapid, almost sudden. Such plants never form tubers. Thus the disease covers only two generations.

In the plants of the second form of the disease he could never

find any mycelium. And so he takes it for granted that all other workers, who have claimed and do still claim that no fungus is associated with this disease, must have studied only the second form of the disease. Hallier as will be seen later in the first form of his disease has studied cases where the Kräuselkrankheit has been mixed with Verticillium, Fäsarium and possibly with Rhizoctonia. In his first paper he describes the mycelium he finds in the infected plants as *Rhizoctonia tabifica*, in his later papers as *Pleospora polytricha* Tul. He made no cultures or infections and comes to the above conclusions simply because he found the perithecia of the above fungus formed on the infected and dead stems, which is a most common thing after the death of the stems of most plants and weeds. Hallier's illustrations of the two forms of the disease are very good and show conclusively that in both cases, he had to deal with the disease now commonly known as stipple-streak.

Oehmichen in 1875 describes the Kräuselkrankheit as described by Kühn and later by Hallier. Out of 512 potato varieties, which he examined, only 20 varieties did show the presence of the disease. He also states that the varieties with light green foliage and fine epidermis suffer most from this disease. As control measure he recommends the use of healthy seed. He finds no fungus associated with the disease.

Schenk in 1875 also describes the Kräuselkrankheit as described by Kühn and agrees with him that no fungus is to be seen in the infected portions. Schenk also saw the primary form of the disease as described by Hallier. The cause of the disease he sees in a disturbance of the assimilation processes of the plant, the actual causes of which must be established yet. Schenk emphasized also the necessity of strict defining and usage of the name Kräselkrankheit, which should be used for the disease described by Kühn and should not be used for other diseases and injuries of the potato plant which may resemble this disease in one or another way.

Schnorrenpfeil in 1876 discussing the Kräuselkrankheit reports that the absolute and specific weight of tubers from stipple-streak plants is much lower than that of tubers from healthy plants. The earlier the plants die from the disease the lower are these weights. He states also that as a rule tubers from sick plants give rise to sick plants and that healthy seed must be used as control measure.

Heimann in 1876 states that the Kräuselkrankheit appeared

on young seedlings even more severely than in other plants of same (?) variety.

Dreisch confirmed in same year the observations of Schnorrenpfeil that tubers from diseased plants give as a rule stipple-streak plants. He finds that cutting the seed increases somewhat the percentage of stipple-streak plants, and states that smaller tubers give a larger number of sick plants than large tubers.

Sorauer in 1877 reviewing the literature on Kräuselkrankheit of the year 1875 states that the real cause of this disease is not a fungus, but that it lies in a defective constitution of the plant itself, which shows itself already in the composition of the seed tuber. An analysis of the healthy and diseased tubers of same size from closely standing plants of same variety showed that the tubers from the diseased plants of same age had very much more potassium than the healthy tubers. The lower percentage of dry matter of the diseased tubers shows, according to Sorauer, that the tubers had remained in a young condition which is inherited.

De Jubainville and Vesque in 1878 describe the stipple-streak disease of potato under the name „frisolée" and „maladie frisée" as follows: „The foliage becomes discolored, the petioles turn down towards the base and roll up completely, the leaves are curled, irregular and covered with elongated spots, these spots increase in size and number and are to be seen also on the petioles and stems. They are at first superficial, later penetrating into the interior of the stem. No tubers or only very small ones are formed. The disease appears after rain in June and July." The authors state that this disease has been considered as a degeneration of the plants due to continuous asexual propagation, but that it has been shown that seedlings are just as severely attacked by the disease. The cause of the disease they see in a too nutritive soil solution and recommend as control measure the use of well decomposed manure and planting of potatoes only on well drained and high lands as recommended by Sorauer.

Reinke and Berthold in 1879 published their work on potato diseases in which they discuss at length the Kräuselkrankheit of this plant. In most of the earlier works, even though they were quite short, it was still possible to recognize with certainty the stipple-streak disease. In this work however, while we recognize with certainty the stipple-streak disease of the potato plant, we recognize also with certainty that the authors were

mixing up two distinct and different diseases, just as Hallier had done. For this reason the writer feels compelled to cite at length some portions of this work in order that the reader may see for himself how the question stands.

The authors distinguish three forms of their disease which they name with the letters A, B and C, and describe as follows:

„A. Towards the beginning of July there appeared the first signs of the disease, which showed itself on some otherwise absolutely normal and vigorous plants. Their lower leaves began to wilt and dry up, usually taking on a yellow color. Curling of the leaflets appeared only in small degree or not at all. No black spots were to be seen on the leaves constantly and when so, only in limited numbers. There were found numerous stems, the leaves of which were wilted and yellow, but not a single brown spot was to be seen on them. In no case did the stems of such plants and only seldom did their petioles show an apparent brittleness. The different shoots of a hill usually did not wilt at the same time, but one after another."

Upon examining sections of so wilted stems they found that the vascular bundles were colored slightly yellow and were full of a heavily branched mycelium, this mycelium was seen in both kinds of vessels but usually in the reticulated vessels. They could follow these mycelia from the base to the very top of the infected plants, which was true in some cases even of the still apparently healthy shoots of same hill. Tnis fungus they described under the name *Verticillium albo-atrum.*

B. This type is to be seen at the same time as A. In this type they find already the symptoms of the third or most advanced stage of the disease. Here also before the middle of July the infected plants are not to be distinguished from the healthy ones, they also reach the size of the healthy and fully grown plants. Stem and leaves are normally developed and apparently healthy. With the appearance of the disease the edges of the leaves begin to curl, but never as bad as in C., there appear brown spots on them, the size of which becomes bigger and bigger, until at last the whole leaf dries up. The petioles are also bent down and there appear on them as well as on the stems discolorations, which result in a sudden wilting and drying up of same. Leaves, petioles and stems are brittle but not so much as in C. The stems, all of which as a rule get diseased, yet not at the same time, show on their underground portions large brown spots and not seldom even longitudinal splitting of the bark. The roots, also show symptoms of the disease. The tubers formed on such plants are less numerous and smaller in size. The microscopic exami-

nation of such plants showed that all portions of the plants above the ground are entirely free from mycelium. In the discolored underground portions, however, a mycelium was always present but only in the parenchym of the bark and never in the vascular bundles.

C. This form appears only on plants obtained from tubers of group A and B. Such tubers which carry in itself the disease and which are usually small, send out in spring shoots which show immediately all the symptoms of an advanced stage of stipple-streak: Such shoots appear later above the ground, develop slower, remain short; the leaves never reach full development, remain small, are drawn together, and do not show the healthy geern color. The leaflets are curled and bent, the main petiole is also bent down. After some time there appear on the leaves and petioles discolorations and black spots. The lower leaves dry up first, the higher standing follow then. At this time there appear black spots also on the stem, at first at the axils of the wilted leaves, then in other places as well, until the whole stem wilts and dries up beginning from the top. If the seed tuber is not exhausted there may be formed new shoots after the death of the first, but they also die before flowering and before forming any tubers. Between the appearance of the first and last shoots from a larger seed-tuber there may pass a long time.

Stems and petioles show by this form of the disease a very high degree of brittleness and break like glass.

Here also no mycelium is found in the portion of the plant above the ground, but here too, as in the case of B., a mycelium was found in the browned cortex of the underground portions of the infected plant.

The first two forms of the disease may appear on one and the same hill and even on one and the same shoot. The tubers of both forms give rise to plants of the third group.

It is more than evident from the foregoing that in the first case the authors had to deal with the Verticillium wilt of the potato, in the second with the primary, in the third with the secondary form of stipple-streak.

They were able to produce experimentally the first form but failed to produce the second form.

Kirchner in 1890 and 1906 describes the Kräuselkrankheit as described by Frank. His illustration of the disease, though poor, shows beyond any doubt that the disease which he describes under the above name is identical with stipple-streak.

Frank in 1896 and 1897 published the results of his observations and studies on the Kräuselkrankheit, which, on account of the fact that the disease attacks the whole hill, he called also „Staudenkrankheit" or vine disease. In what was called at the time „Kräuselkrankheit" he distinguishes several diseases which he considers as closely related, „as there are seen often intermediate forms", yet they are in themselves distinctly different and in some of them even the curling was absent. So that he tinks it undesirable to apply also to them the name „Kräuselkrankheit". For that reason he suggests for all of these diseases the common name of „vine disease". Following is his description of the various forms of this disease, most of which represent forms of stipple-streak.

„1. Real Kräuselkrankheit with downwards bent leaves and dark brown spots, which come out on the lower side of the leaf veins. The whole plant remains smaller than the healthy ones, has not the healthy green color and is distinctly curled. The leaves are often peculiarly brittle. All leaves according to their age take on the above symptoms and that as soon as they appear from the growing point of the stem. The leaves break off easily and die after reaching a certain age. Here are characteristic the small dark brown spots which appear on the leaves even while they are still perfectly green and vigorous. These spots are usually found on the veins of the leaves and most commonly on the lower side of same. From the veins the black spots extend in the surrounding leaf tissues. Such elongated spots can be seen also on the lower side of the petioles and even on the stems, which sometimes reach as far as the base of same and even down along the stolons and young tubers. No fungus is present in any of these spots. The spots and dead cells on the lower side of the leaf veins and petioles are the immediate cause of the curling and bending of same as the growth of the upper portions proceeds more rapidly than that of the lower". This form is, according to Frank, the most common one and has been known for a long time as Kräuselkrankheit. This form as seen from the above description represents beyond any doubt secondary stipple-streak.

2. Real Kräuselkrankheit. This form is exactly the same as the first except that here the black spots are limited to the veins of the leaves.

This form resembles very much the crinkle disease of potato.

3. Real Kräuselkrankheit. This form resembles completely the first form except that no black spots are to be seen whatever, not even on the veins. As a rule the leaves do not die in

this case as rapidly as they did in the first and second case.

From the above it seems evident that in this case Frank has had to deal again with crinkle or advanced cases of potato mosaic which resemble somewhat the secondary form of stipple-streak.

4. „Staudenkrankheit without typical curling of the leaves but with small black spots. Here the spots are formed entirely in the mesophyll between the veins. The veins remain normal and there is no curling of the foliage. The shoots here are not so short as in the case of the real Kräuselkrankheit. But here also as in the first three forms all shoots of a hill do eventually get the disease and the careful observer cannot but notice that there are in the fields intermediate forms between this and the first form, where the spots appear sometimes more on the veins in others more between the veins, which shows the close relation of the various forms of this disease". This form of the disease is nothing but the primary form of stipple-streak.

5. „Pockenflecke" of the leaves. Here Frank describes the early blight of potatoes which he supposed to be also a form of Kräuselkrankheit.

Frank is of the opinion that the cause of the Kräuselkrankheit is not a fungus and that it lies in the plant itself, which is shown by the fact that only certain varieties, Liebscher for instance, are attacked by it while other varieties remain perfectly healthy.

Prillieux in 1897 briefly described the „frisolée" disease of potato as follows: „The plants are dwarfish, the leaves are small, abnormal and curled. On the stem, petioles, and leaves there appear black spots, at first superficial then extend in the interior of the stem, the leaves wilt and the plant dies completely". He then discusses Schenk's (?) opinion that an Alternaria sp. is the cause of this disease and states that it must be established yet whether it is the real cause or only a saprophyte, appearing on the diseased plants.

Sorauer in 1897 described a potato disease under the name „Stippfleckenkrankheit" which is nothing but the primary form of stipple-streak. The disease is characterized by the appearance of numerous small angular black spots on the leaves of the otherwise healthy and normally developed potato plants, it spread rapidly on a variety with lighter foliage and less so on a variety with darker foliage.

The lower leaves died and became brown while single plants died completely. The upper leaves have a healthy green color or are slightly yellowish and are always covered with more or fewer black spots. Often the upper leaves are more spotted than

the older leaves. The spots are irregularly spread over the leaves, have a dark brown to black color and are small and angular, dry, and on both sides of the leaves, sometimes running along a vein, thus forming a black streak over the green leaf. In two cases he saw a mycelium in such spots in one case he saw no mcyelium.

SECOND PERIOD. 1900—1922.

Coming to the literature written on stipple-streak after the year 1900 we see an entirely different situation: Whereas during the preceding one hundred and twenty or more years the stipple-streak disease of the potato plant was always known and considered as a distinct and different disease, in its nature being understood to a certain extent, it now, in spite of the fact that it continued to appear and in some years even did considerable damage, suddenly ceased to exist as such in order to reappear again in various countries and in many papers as a „new" and „unknown" disease, to which more than half a dozen new names have been given, our present knowledge of which being as limited as that of our predecessors of the eighteenth century.

It is very discouraging indeed to think that during a period of one hundred and twenty years of extensive and careful observations and studies, in which have taken part so many and so prominent workers no light could be thrown on the nature and cause of the stipple-streak and related diseases of potato beyond the fact that it is a systemic disease, that it is transmitted with the seed tubers, and that the plants once infected, including their progenies, never recover from the disease.

Sorauer's last words on this subject written at the beginning of the present century may serve perhaps as an illustration of the above and as a summary of all studies on this subject up to the beginning of the second period in the studying of running-out diseases of potato:

„Über die Kräuselkrankheit bringen die eingelaufenen Berichte keine neuen Mitteilungen, sondern nur Bestätigungen älterer Angaben, von denen der Mangel von Parasiten wohl die Wichtigste ist. *Wir sind über die Ursache der Kräuselkrankheit noch durchaus im unklaren.*[1]) Für die Ansicht, dass die Krankheitsursache bereits in der Mutterknolle zu suchen sei, deren einzelne Augen bei ihrer Anlage schon den Krankheitskeim mitbekommen, spricht der Umstand des platzweisen Auftretens einzelner

1) The italics are mine.

kranker Exemplare zwischen den gesunden Reihen und das Erkranken einzelner Stengel an derselben Staude".

„It seems enveloped in an impenetrable mystery", wrote Billingsley in 1792 regarding the cause of same disease.

This very fact perhaps made the desire to understand and explain this „mystery" so much greater among the workers on this subject, that it led to the setting up of an endless chain of most opposing and varying theories and most impossible explanations regarding the cause of the disease. As an example of this can serve no one better than Sorauer himself (1904). This able phytopathologist and most illustrious representative, if not founder of the school of predispositionists, which almost revolutionized the phytopathological science, in his desire to explain the nature and cause of the Kräuselkrankheit, a subject which has interested him for over 30 years, was led to believe, evidently after discharging all other possibilities, that the cause of the Kräuselkrankheit lies entirely in the environmental conditions: „Man braucht dabei nicht an Parasiten zu denken, sondern kann sich auch vorstellen, dass zur Zeit, als einzelne Knollen angelegt wurden, ungewöhnliche Ernährungsverhältnisse (hochkonzentrierte Nährlösung, Wasserarmut u.dgl.) vorhanden gewesen sind, die eine schwächliche Anlage der Augen veranlasst haben. Wenn derartige Augen im nächsten Jahre unter besonders günstigen Wachstumsbedingungen austreiben, so kann die Entfaltung der Triebe normal stattfinden. Wenn aber ungewöhnliche Witterungsverhältnisse, wie z.B. grosse Hitze und Trockenheit im Boden, die in der Anlage schwächlichen Triebe beeinflussen, dann wird der Stengel sich wenig strecken und das Laub sich in geringem Masse nur entfalten können. Aehnlich wie bei den Salzpflanzen kommen dann Verkürzung der Achsen und glasige Beschaffenheit nebst Brüchigheit zustande." This explanation of the cause of potato stipple-streak and related diseases has been upheld in one or other form by numerous workers during the last fifteen years and is accepted as correct even now by Hiltner and other German workers.

Jones travelling through Europe in 1904 to study the resistance of the potato to diseases saw in Germany with Appel and Sorauer a disease causing spotting of the potato leaves, that was different from the Alternaria leaf spot. In the spots he as well as Sorauer and Appel did not find any fungus mycelium. In the trial grounds of the University Farm at Cambridge-England he saw again the same disease and reports that „there was a considerable difference in the amount of spotting of the

various varieties, but none was altogether free from it." It seems highly probable from the above that Jones has had under observation the primary form of stipple-streak.

Massee in 1905, also in both editions of his book on plant diseases, describes a disease under the name potato leaf-curl, which resembles very well the stipple-streak disease. „The curling of the leaves is usually the first indication of the presence of the fungus, although the base of the haulm is the portion first infected, and the curling of the leaves is due to the ascent of water and food being checked by the upward growth of the fungus mycelium in the tissues of the haulm....

At a later stage, the fungus breaks through the tissues to produce its fruit, which is indicated by the presence of numerous irregular, blackish, minutely velvety patches scattered over the surface of the haulm and leaves.

It has been found that in some instances the mycelium of the fungus passes down the haulm into the tuber. In such cases the mycelium in the infected tuber passes into the sprout and again produces the disease in the haulm and leaves.

Neither the leaves nor the haulm above ground can be infected by the spores of the fungus". Only the young sprouts can be infected according to Massee with the spores of the fungus, which he identifies with *Macrosporium* (*Alternaria*) *solani*. The disease as described here by Massee cannot be the early blight of potato, caused by *Alternaria solani* and it seems very likely that Massee seeing the conidia of some saprophytic Alternaria or Macrosporium sp. on the brown spots of the stipple-streak infected plants has considered it as being the cause of the disease and has mistaken the latter for the early blight of potato.

In 1906 appeared in form of a leaflet Appel's first description of stipple-streak. He considers it as a vascular disease; expressing itself in a rotting and browning of the vascular ring of the tubers and being caused by bacteria, hence his name „bacterial-ring" disease. When such tubers are planted, according to him, one of the following three things may be the result:

1. Part of the tubers though externally normal and in spite of the fact that some sprouts may have been formed on them, the latter are attacked and killed before reaching the surface. Here is to be seen an extensive root or small tuber formation. This, he says, is not very typical of this disease as it is seen also in other potato diseases.

2. Other tubers germinate, the plants reach the surface of the soil but remain small, stunted and die shortly after. On the

lower portion of such plants are seen brown colored ruptures, the leaves of such plants are often but not always covered with black spots and soon fall off. Such plants usually die during the month of June.

3. Still another group of plants develop perfectly normally and not before midsummer single or all of their shoots become covered with brown spots and die. Here also the spotting does not appear always. While the plants of the first two groups usually form no tubers, those of the third group give an apparently normal yield. These tubers, however, are to be feared most as they carry over the disease.

Though Appel saw plainly the two stages of the disease, he did not realize that they represent different ages of same and not different degrees of infection as he supposed. He thinks that apparently several closely related bacteria are the cause of the disease and that they undoubtedly must be present in the soil. They cannot attack the healthy and uninjured plants but enter into the plants only through wounds, especially through the freshly cut surface of tubers by which the vascular bundles are being exposed. As control measure he recommends the use of healthy and uncut seed. His later descriptions of this disease in collaboration first with Kreitz and later with Schlumberger have same content. While it is more than certain from the above and from Appel's photos of this disease, that in this case he has had to deal partly with stipple-streak, it is just as evident that the above name as applied by him covers two distinct diseases, which he himself suspected several years later (1913, p 12). The disease he describes above as seen on the green plant is stipplestreak, the disease seen by him on the tubers on the other hand has nothing to do with stipple-streak and may be the same as the disease described several years later by Smith (1911) and Spieckermann (1914).

It seems from Appel's works (1906—1907) that the name Kräuselkrankheit at that time has been used quite indiscriminately for designating several different diseases. These diseases he together with his collaborators describes in 1906, 1907 and 1913 as:

1. Kräuselkrankheit proper, expressing itself in a marked shortening of the stems, crinkling of the leaves and a distinct brittleness of the whole plant. This form may represent, as we understand the question to-day, advanced stages of mosaic, crinkle, or stipple-streak.

2. Leafroll expressed in a retarded growth and rolling of the leaves, here for the first time described and named.

3. Bacterial ring-disease as described above, which is in reality the Kräuselkrankheit of olden days plus a bacterial tuber rot disease.

Schander in 1908 trying to verify the above work of Appel came to the conclusion that Appel's ring disease can be recognized only on the plants and that the tubers do not show the symptoms described by Appel. He also observed that in 1907 in some cases up to 60—80 % of the tubers had black or discolored vascular rings in which bacteria were present, yet when such tubers were planted they gave perfectly healthy plants which gave a good yield. He comes therefore to the conclusion that the discoloration of the tubers in those years has been of a temporary nature, being the result of the unfavorabele weather conditions during the summer and that it has nothing to do with the disease as seen on the plants.

In a second work Schander says also that the ring disease as observed on the plants is transmitted by the seed and that the yield decreases so rapidly that already the second or the third year no tubers are formed whatever. Of the cause of this disease he is not certain.

Brandl in 1909 expressed the opinion that leafroll and appel's bacterial-ring disease are very likly different stages of one and the same disease: The first being the lighter the second the more severe form.

Miss Dale in 1912 attributed the „blindness' of the potato tubers, a disease which she has been studying since 1909, to *Verticillium albo-atrum*. The tubers are attacked by the disease on and around the eyes, the buds are destroyed and if the „blind"tuber is cut through the eyes it will be seen that the diseased area is confined exclusively to the eyes and to a narrow zone immediately below the cortex, which is thickened by cork formation. In this zone she found the mycelia of *V. albo-atrum*, whereas the whole of the interior of the tuber remained sound. When thus infected tubers were planted some of them rotted away, some remained sound but produced no shoots, others formed sprouts, which developed into shoots. These at first appeared healthy, but later most of them showed signs of leaf curl and leaf roll, becoming yellow in color, and gradually withering and dying from below upwards. The mycelium of the fungus is not present in the stem and leaves of the plant. The subterranean stems, however, especially those nearest to

the old tuber were covered with elongated brown patches due to *V. albo-atrum*. These brown patches spread from the seed-tuber up to the new shoots and along the stolons.

It is quite evident from the above description of the „blindness" of potato tubers, that Miss Dale worked with stipple-streak, though she had mixed up with it a number of other diseases and attributed it to *V. albo-atrum*, which as a matter of fact is a well known vascular parasite of potatoes, but does never attack the tubers in the way described by Miss Dale. It seems that the fungus she has been seeing has been a secondary organism.

On the leaves of the above plants, however, appeared at the same time a bacterial disease, which Miss Dale described in the same year in a second paper. Here also she seems to be dealing with stipple-streak. The leaves on which she suspected her bacterial disease became somewhat wrinkled, becoming slightly yellow and covered with small brownish spots. In sections of the brown spots of such leaves she saw that the cells were densely filled with „granules" showing active movement, these granules contrary(?) to other cells granules are stainable and were found to be bacteria. Five days later, she writes, the diseased plant showed symptoms of „leaf curl". „The leaves were rolling up at the edges and were going yellow in large patches and the veins of the leaves were turning brown from the edge towards the centre of the leaves. The leaves gradually became more yellow and dropped off, from below upwards." The stems of the plants in some cases were also yellow and covered with elongated brown patches. From the above it becomes evident that she has been working with stipple-streak, even though her description of the disease is such that it leaves no doubt that she has had not one, but several different diseases on same plants, all of which she considers as one disease.

Upon sectioning some of the infected leaves and veins of leaves she saw that in them are always present large stainable tubes, passing through the cells and nearly all ending in cells filled with stainable granules. These tubes begin forming on the surface of the leaves and pass inwards, piercing the epidermis where two adjacent cells are in contact, but never enter through the stomata.

From infected leaves she isolated a bacterium with which she made successful infections and produced same symptoms. It is however very difficult to analize her infection experiments because very few of them were successful and because even in those cases the macro and microscopic symptoms were not in all cases alike and besides this she claims to have made success-

ful infections with a second organism as well, in which case as in some of the former no tubes were seen in the infected portions, though the bacteria were present in the infected cells.

One thing is certain in Miss Dale's work and that is that the disease of potato tubers she describes under the name of „blindness" is stipple streak and that planting stipple-streak infected tubers she must have had besides various other possible diseases also stipple-streak, something which sometimes becomes quite evident from her description. The causative organism of her disease she describes under the name *Bacillus tubifex*.

Orton in 1913 discussing leaf roll, curly leaf and other new potato diseases writes the following of stipple-streak: „Elongated or angular spots appear on leaves, following the veins. The leaves wither and hang dry on the plant, which soon dies. Cause unknown". Here he first applies the name „streak" to this disease and from his short but exact description it is evident that he had to do with the primary stage of stipple-streak Orton however did not recognize the secondary stage of the disease and considered it in some cases as curly-dwarf in still others as an advanced stage of leaf roll. That the above is correct and that most of the cases which Orton has considered as curly-dwarf and in some cases even as advanced leaf-roll must have been cases of secondary stipple-streak, is seen from the fact that all the four groups of tubers shown on plate XIII of his bulletin on potato diseases (1914) and representing the yield of curly-dwarf and leaf-roll plants with their pronounced splitting show quite conclusively that they are the tubers of heavily infected stipple-streak plants. This splitting and bursting of the tubers is a common symptom of stipple-streak, especially when the plants are vigorous and the formation of tubers rapid; it has never been observed by the writer on other potato diseases or on what is called by some curly-dwarf. Prof Quanjer who has had under observation for many years a large number of potato varieties from all parts of the world and infected with all the known degeneration diseases of this plant has also never seen this splitting of the tubers in any other potato disease. Fig. 2 of plate IV of same work can hardly represent an advanced stage of leaf-roll, while the shrunken, hanging and partly broken off leaves, the unbranched stems and the general habit of the plant indicate that this may have been also a case of secondary stipple-streak.

Appel in 1915 expressed again the idea that stipple-streak, which he now also calls streak, is one of the diseases described

in 1897 by Frank under the collective name of „vine diseases". He also thinks that it resembles in some stages curly dwarf, whereas where it is but weakly developed (the primary stage) it does not resemble curly dwarf. He describes the disease as seen on the plants, considers it as a bacterial disease, though the cause, he says, has not yet been discovered and adds, contrary to his first ideas on this question, that it has not been proved whether this disease is transmitted by the seed.

Barrus in 1917 discussing potato streak says that it produces a condition somewhat similar to the degeneration diseases. He saw both phases of the disease without making any distinction between them and describes the symptoms of the disease as seen on the stem and leaves. He saw the disease spread on to the neighbouring healthy plants. „However, an attempt to obtain an artificial infection by the inoculation of healthy plants with bacteria from a culture made from an affected stem was without success". Planting the following year (1916) the apparently healthy tubers from the infected plants he got again the disease, whereas tubers from healthy plants planted with the above as checks remained healthy during the whole season. No other healthy plants were observed to contract the disease that year.

Speaking of the nature of the disease he says: „It is evidently infectious and of a bacterial nature. Careful work should result in the isolation of the causal organism. Apparently this micro-organism can be carried over winter on the seed, and if this be the only way, disinfection should be an effective remedy".

Güssow in 1918 reports stipple-streak from Eastern Canada and the Islands of Bermuda. He describes and pictures typical stipple-streak under the name „Leaf Streak". „The symptoms, he writes, show up very suddenly towards the end of the vigorous growing season and the leaves are quickly killed. At times the leaf stalk will show one or more dark streaks in its interior when it is held up against the light. The trouble looks typical enough for a bacterial disease, but so far, isolations of any kind of organism have proved unsuccessful". The disease is transmitted by the seed-tubers.

Orton in 1920 published his observations on stipple-streak up to date and describes the disease as seen in the first stage. He is of the opinion that: „Potato streak is a disease of the foliage, attacking fullgrown and otherwise normal and healthy plants and frequently progressing rapidly to destroy them", while

the tubers remain normal. In warning that the disease should not be confused with advanced stages of leaf-roll or mosaic dwarfs, or otherwise degenerated plants he says: „There is, for example, a disease not uncommon in our trial grounds, marked by weak, erect stems, from which frequently the spotted leaves fall prematurely, from the base upwards, so that a palm-tree effect is produced." Which is nothing but the secondary stage of stipple-streak.

The cause of stipple-streak he considers as doubtful and thinks that in its appearance and general course it presents striking similarities with some of the well known bacterial diseases, such as *Ps. Malvacearum* on cotton and *Bact. michigensis* on tomato. He adds also: „The writer was confident that bacteria would prove to be the cause, but efforts to isolate an organism have thus far been futile. For the most part plates poured from the discolored areas remained sterile. Colleges have made similar attempts, with similar negative results. It is believed, nevertheless, that eventually an organism will be found and shown to cause potato streak". Orton noticed a marked varietal resistance and that some plants remained entirely healthy, while others directly alongside were destroyed. He observed more stipple-streak on European varieties such as Factor, than in American varieties. The seedlings with large per cent of stipple-streak which he examined were for the most part hybrids of European varieties and this, he thinks, may account for their greater susceptibility.

Murphy in 1920 in an abstract in Phytopathology considers the secondary form of stipple-streak as one of the diseases causing „running out" of potato seed. He gives to it the name „leaf drop" and describes it as follows: „The disease causes extreme dwarfing, gradual death of the leaves from below upwards, and premature death. It may be identical with Appel's bacterial-ring disease and with a trouble described by F. C. Stewart." He states also that there are indications that the disease is of European origin.

Murphy also while speaking of „leaf drop", which is nothing else but the secondary stage of stipple-streak, and which he has been observing for 5—6 years, states in a letter of Nov. 17, 1919 to Prof Quanjer that streak (he means the primary stage of stipple-streak) is a different disease, new for his plots, which he considers as being caused by a bacterium and states that he has been able to produce the disease by inoculating healthy plants with bacteria isolated from streak plants, while

leaf-drop he considers as one of the diseases causing running out and adds „So far we have no proof of any connection between „streak" and „leaf drop" or „crinkle".

Quanjer in 1921 also described briefly and illustrated the stipple-streak disease of potato under the name of streak. In same work is given also his first description of crinkle. The secondary forms of these two diseases are identical with the various „dwarf" diseases of the potato plant.

Schultz and Folsom in 1922 came to the conclusion that streak is „closely related to mosaic and similar diseases of the Irish potato, being frequently associated with them in the field, having initial late-season symptoms in new leaves only, usually spreading to all connected parts of a hill, and spreading to other hills with the production either of late-season symptoms the same year or of tubertransmitted early season symptoms appearing the following year. In 1921 juice from a streak plant applied to 20 mutilated Green Mountain and Irish Cobbler plants caused infection in 19, with typical symptoms appearing in some in 12 days". They expressed also the opinion that the rareness of streak in commercial fields of North-eastern Main may be due to self-elimination.

The writer of this paper in 1922 also gave a detailed description of stipple-streak in its whole development and in all of its forms. A careful reading of this work, also of Quanjer's and Schultz' works on leaf roll, mosaic and crinkle is necessary for the proper interpretation of the older literature on stipple-streak and related diseases of potato.

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